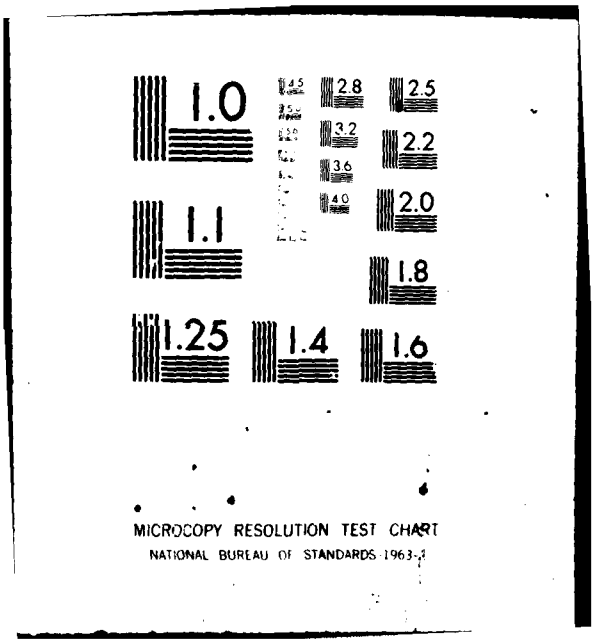
AD-A083 742 OREGON GRADUATE CENTER BEAVERTON F/G 20/6
WAVE PROPAGATION IN PARTICULATE MEDIA,(U)
APR 80 R A ELLIOTT N00014-79-C-0897
UNCLASSIFIED NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
	AD-A083742	

4. TITLE (and Subtitle)
WAVE PROPAGATION IN PARTICULATE MEDIA

5. TYPE OF REPORT & PERIOD COVERED
Annual Summary
9/1/79-4/15/80

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Richard A. Elliott

8. CONTRACT OR GRANT NUMBER(s)
N00014-79-C-0897

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Oregon Graduate Center
19600 N.W. Walker Road
Beaverton, Oregon 97006

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
NR394-045

11. CONTROLLING OFFICE NAME AND ADDRESS
Office of Naval Research, Physics Program Office
800 N. Quincy Street
Arlington, VA 22217

12. REPORT DATE
15 April 1980

13. NUMBER OF PAGES
10

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Annual summary rept.
1 Sep 79-15 Apr 80

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Optical scattering, pulse stretching, cloud simulation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Progress in developing techniques for producing well characterized scattering media from dielectric liquid emulsions and the design of equipment to measure their optical properties and their effect on laser pulse propagation are outlined.

390077

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

WAVE PROPAGATION IN PARTICULATE MEDIA

Richard A. Elliott

Annual Summary

September 1, 1979 - April 15, 1980

Contractor: The Oregon Graduate Center

Sponsor: Office of Naval Research
800 N. Quincy Street
Arlington, Virginia 22217

Contract Number: N00014-79-C-0897

Effective Date of Contract: September 1, 1979

Principal Investigator: Richard A. Elliott

Wave Propagation in Particulate Media

Introduction

The purpose of this project is to study optical propagation in a medium consisting of random, discrete scattering centers with a view to establishing the effects of clouds and fogs on optical communication systems. The degree of pulse stretching, depolarization and beam spreading are to be determined as functions of the scattering geometry and the physical properties of the scatterers and compared with the predictions of theoretical models.

An appropriate scattering medium for these experiments is an emulsion of two dielectric liquids since the indices of refraction of both the scatterers and the bulk medium can be varied by choosing different substances and the size of the droplets of the dispersed phase can be controlled by the method of preparation. In addition, emulsions can be stabilized with surfactants and can have much higher number densities than can be maintained in cloud chambers. This allows one to simulate the effect of say a kilometer of cloud in a laboratory scale scattering experiment.

The initial phase of the project has been devoted to designing, constructing and assembling the required equipment and to perfecting the techniques of preparing monodisperse emulsions. A description of this work follows.

Technical Progress

1) Scattering Medium Preparation

The scattering medium must of course be completely characterized in order to extract meaningful information from the experiments.

Thus it is of prime importance that the droplet size distribution of the emulsion and the refractive indices of both the dispersed and bulk phases be known precisely. The latter are well known for most substances and in any case are easily measured. The size distribution can be determined directly, if tediously, by microscopic examination. It is also possible to use Mie scattering theory to infer both the relative refractive index and the size of the scatterers from the angular scattering functions of the medium if a sufficiently thin layer is used to eliminate multiple scattering effects. We intend to use both direct microscopic examination and the inversion techniques. The design and construction of apparatus to measure the angular scattering function will be discussed below but to date we have relied on microscopic study of the emulsions in refining our preparation techniques.

One emulsion we have been working with is an oil-water system stabilized with sodium dodecyl sulphate (SDS). We have found that mineral oil and 0.2% by weight SDS in water form stable emulsions and the volume fraction of the oil droplets can be made as great as a few percent without problems of agglomeration. The index of refraction of the oil is 1.4802 and that of the bulk phase is 1.3332 yielding a relative index of 1.1103. Other substances can and will be used to obtain higher relative indices, e.g., di-iodomethane in water has been briefly studied and yields a relative index of 1.304. For the present we are using the oil-water system to perfect our method of producing monodisperse size distributions.

The standard preparation procedure now in use is to vigorously agitate 1% by volume oil in the SDS/water solution to form a coarse emulsion which is then passed up to five times through a filter of a given pore size. This produces a droplet size distribution with mean diameter approximately that of the pore size but the range in diameters is rather large and the distribution is skewed toward the small end. For example, if an 8 μm pore size is used the droplet diameters range from around 2 to 10 μm. Two types of filter have been tried, millipore and nucleapore, with the latter seeming to work best for producing larger droplet sizes but both yield similar distributions.

We have expended considerable effort on reducing the variance of the size distribution with some success. Since the rate at which the oil droplets rise due to buoyancy is proportional to the square of their diameter it would seem relatively simple to exploit this to obtain droplets of uniform size. However as a practical matter the speeds involved are so low (100 μm/min for 5 μm diameter droplets) that great care has to be taken to isolate the system thermally and mechanically to avoid convection currents and mixing in the separation apparatus.

A technique for extracting droplets with a particular mean diameter and standard deviation has been developed although the efficiency is low and we are continuing to improve the method further. It involves carefully introducing the emulsion as it comes from filtration into the bottom of a column of 0.2% SDS/water solution (see Figure 1). After a time interval depending on the droplet diameter

desired all droplets larger than that size have reached the upper surface. By adding a small volume of SDS/water these large droplets are forced out of the side tube and discarded. Some time later additional SDS/water is added forcing out a volume of the medium which contains the droplets of the desired size but none smaller than a given size since these have not yet reached the surface. In practice we find that the separation is not complete due to some mixing caused by uneven flow rates near the surface of the liquid when removing the samples through the side tube. Repetition of the procedure outlined reduces the variance further and thus this method can be used to produce the required degree of uniformity. Modifications to the apparatus are now being made which we hope will improve the efficiency of the separation process.

ii) Design and Construction of Apparatus

The first optical measurements which will be made are those to determine the single scatter angular intensity functions which will be inverted to obtain information on the size distribution and refractive index. The angular scattering functions will also be used to calculate the first and second moments of the cosine of the scattering angle since these quantities appear as parameters in theoretical models of the multiple scattering problem.

Apparatus to obtain the angular intensity functions is being built and is nearly ready for testing. The scattering cell itself is a cylindrical tube 1 cm in diameter with a 1 mm bore. One side of the tube has an optically polished flat so that a collimated laser beam

may enter perpendicular to the cylinder axis without focusing effects (Fig. 2). A low noise photodiode is mounted on an arm which pivots about the cylinder axis and is driven by a constant speed reversible motor. The signal from the photodiode is converted to digital form by a microprocessor controlled 14 bit A/D converter and recorded on magnetic tape for subsequent analysis.

Pulse stretching and beam divergence measurements which will proceed when the emulsion has been characterized will utilize a cylindrical scattering cell 10 cm long by 40 cm diameter (Fig. 3). The cylinder is mounted with its axis horizontal and rotates at 1 rpm in order that an emulsion can be placed in the cell and maintained for long periods of time without problems of agglomeration or creaming, i.e., formation of a layer of oil droplets on the surface. The incident light enters along the cylinder axis through a 2 cm diameter antireflection coated window which together with a black anodized baffle can be moved over a range of 0.5 to 10 cm from the 40 cm diameter plate glass exit window. This will allow a full range of measurements to be made for a variety of path lengths and optical densities with each type of emulsion.

Our current plans are to use a passively mode-locked Nd:YAG laser which we have assembled for the pulse stretching measurements. Each mode-locked burst from the laser contains around twenty 80 μJ pulses each 50 picoseconds in duration spaced at 10 nanosecond intervals. The pulse train then passes through an angle tuned KDP crystal frequency doubler to convert some of the infrared (1064 nm)

pulses to the visible (532 nm). The green pulses carry around 20 μJ energy and are 35 picoseconds in duration. A single one of the green pulses will be selected from the train and transmitted through the large scattering cell. The radiation emerging from the cell will be detected and displayed with a Hamamatsu streak camera capable of 5 picosecond time resolution.

Summary

A technique for producing well characterized particulate scattering media has been developed. The media are emulsions of two dielectric liquids which can have a wide range of refractive indices. The size of the dispersed droplets can also be varied and the size distribution controlled by means of filtration and exploiting the difference in speed with which droplets of different size move through the medium under the influence of gravity.

Two pieces of scattering apparatus have been designed and are nearly completed. One will be used to measure the single scatter angular intensity functions and the other for the multiple scattering experiments. A passively mode-locked Nd:YAG laser has been assembled and tested. It will be used together with our Hamamatsu streak camera to conduct the pulse stretching measurements.

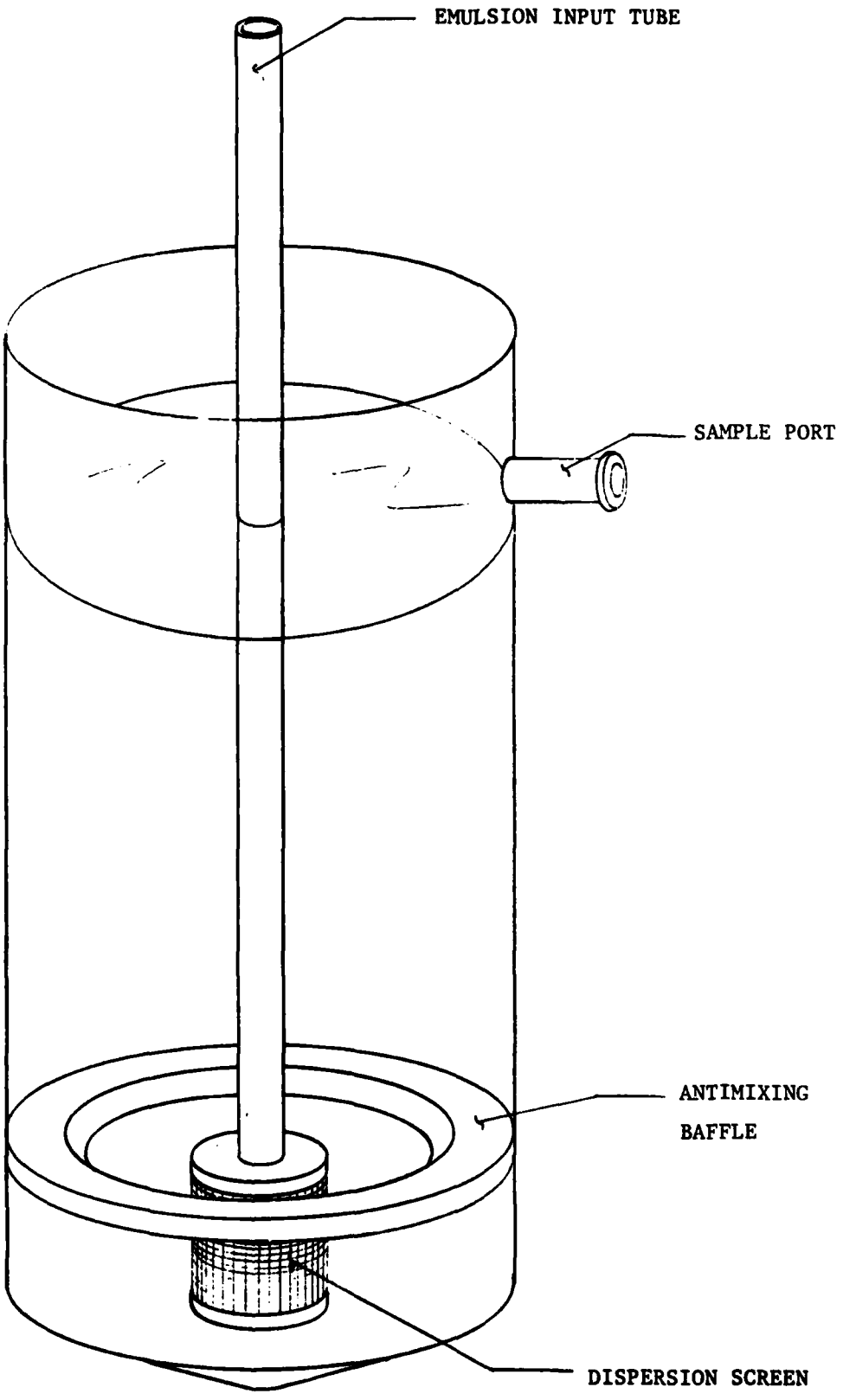

EMULSION INPUT TUBE
SAMPLE PORT
ANTIMIXING
BAFFLE
DISPERSION SCREEN

Figure 1.

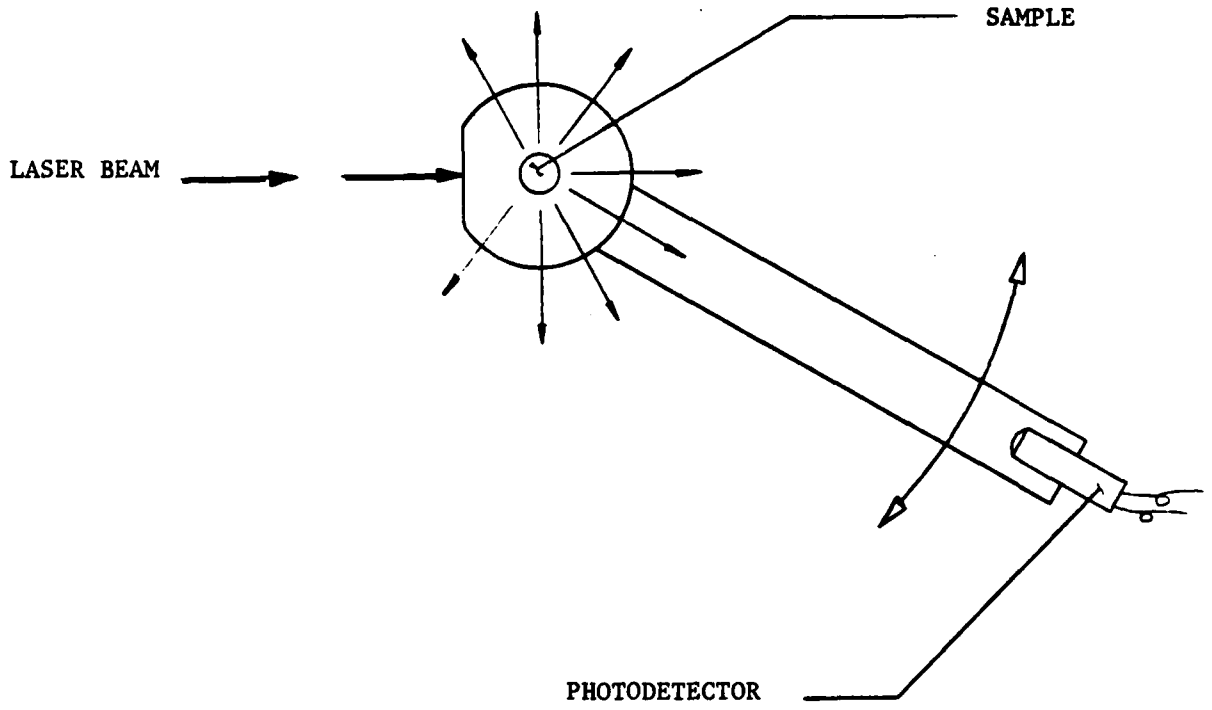
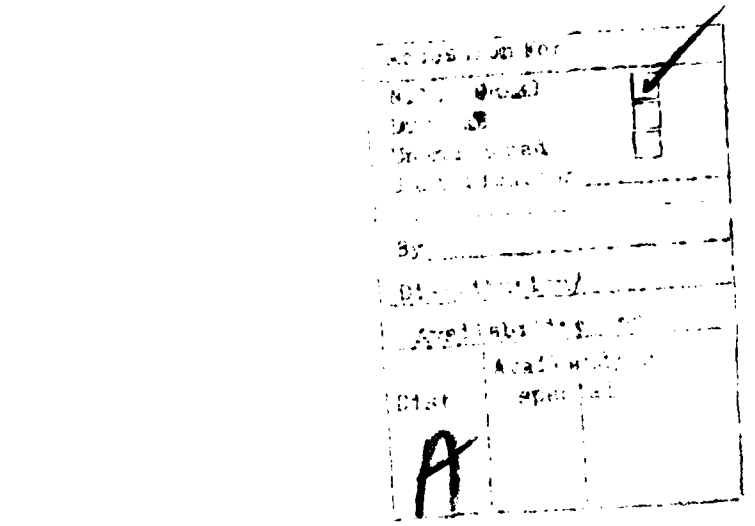


Figure 2.



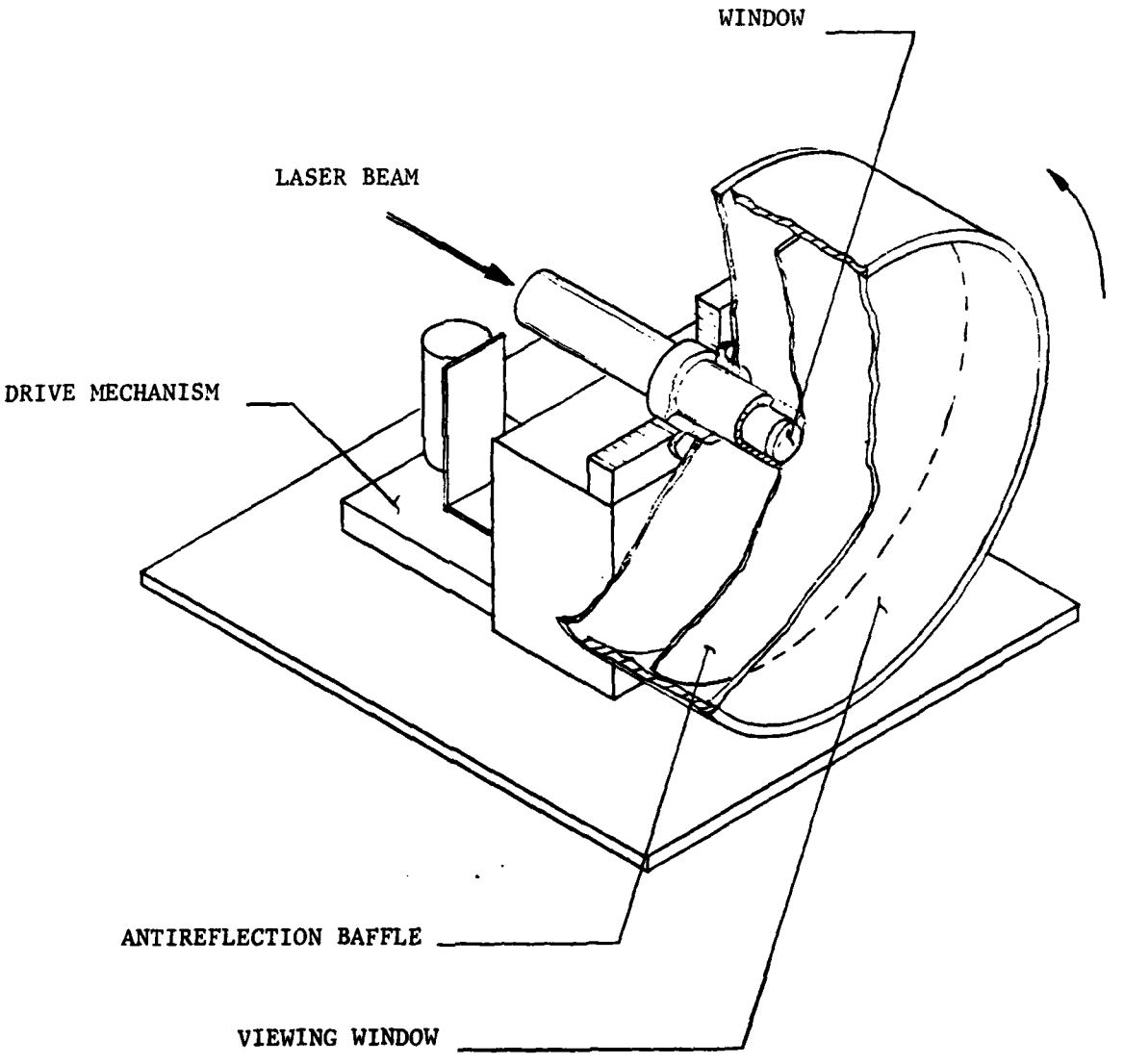

WINDOW
LASER BEAM
DRIVE MECHANISM
ANTIREFLECTION BAFFLE
VIEWING WINDOW

Figure 3.